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The corrosion and tribocorrosion resistance of PEO composite coatings containing α-Al_2O_3 particles on 7075 Al alloy

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ABSTRACT

Plasma electrolytic oxidation (PEO) of 7075 Al alloy was carried out in silicate base electrolyte containing 200 nm diameter α-Al_2O_3 particles for producing composite coatings. The process was performed under a soft-sparking regime using a pulsed bipolar signal with several concentrations of α-Al_2O_3 particles. It was found that the incorporation of α-Al_2O_3 particles into the coating did not significantly alter the thickness and roughness of the coating. However, the α-Al_2O_3 particles were detected on surface of the composite coatings. Corrosion tests showed significant improvement in corrosion performance of the composite coatings due to the efficient pore blocking provided by α-Al_2O_3 particles, which enhances the barrier performance of both inner and outer layers of the coatings. However, the long-term EIS measurements showed that the performance of composite coatings becomes close to that of particle-free coating after 56 days of immersion in chloride containing solution. Tribocorrosion tests showed that adding 3 $g \cdot l^{-1}$ of α-Al_2O_3 particles to the electrolyte bath decreased the lost wear volume of the resulted coating from 30 to 10 mm^3 ($\times 10^{-3}$). Higher α-Al_2O_3 particles concentration (i.e. 7 $g \cdot l^{-1}$) showed detrimental effect on both corrosion and tribocorrosion performance of the coating.

1. Introduction

Aluminum properties such as high atmospheric corrosion resistance and strength-to-weight ratio are attractive for aerospace and automobile industries. Despite many advantages of aluminum alloys, their weakness in mechanical and tribological properties are bolded, specially, low hardness and wear resistance as well as high friction coefficient which brings certain restrictions in tribological applications [1].

Alumina ceramic coatings show great potential as hard, wear and corrosion resistant coatings on aluminum and its alloys. Various techniques including chemical vapor deposition (CVD), ionization assisted magnetron sputtering and thermal spray are available to deposit alumina coatings, most of them involve high temperature operations, not suitable for aluminum. As an alternative, the coatings produced by plasma electrolytic oxidation (PEO) are easy to apply on metallic components with complex geometry [2, 3].

7075 Al is one the most interesting alloys in aero-space, robotic, transportation and etc. It is a heat-treatable alloy and because of high alloying element contents (mainly Zn), the conventional or hard anodizing is not a suitable surface treatment for improving its corrosion resistance. This statement becomes even more stringent when the alloy is subjected to T6 (precipitation hardening) heat-treatment. Conventional and hard anodizing have some common features, since they both induce the formation of amorphous alumina coating, even if hard anodizing allows to prepare coatings with higher thickness and hardness [4]. Plasma electrolytic oxidation is less sensitive to alloying elements and precipitations in the substrate. Moreover, a very thick crystalline coating with improved engineering properties can be produced by the PEO, whose corrosion resistance has been widely studied in the last years [5–11]. An effective strategy to tune the properties of the PEO coating is the incorporation of electrolyte constituents, i.e. ions and/or suspended particles appositely added to the solution. In the latter case, the process is carried out using a suspension and by selecting the concentration and composition of the suspended particles; it is possible to prepare composite coatings [6, 12–30]. An incorporation of suspended particles during the PEO is reported for Al [1, 6, 10, 13, 14, 17–20, 31], Ti [15, 16, 23, 24] and Mg [25–27, 29, 30, 32] alloys. The incorporation of particles into the coatings without formation of new phases and/or reactions is called inert, while the incorporation with formation of a new phase is called reactive [29]. Based on the incorporation mode, which itself shows dependency on many factors, composition and morphology of the obtained coatings will be different [33]. Focusing on Al alloys, a survey of the published literature shows that the addition of zirconia, titania and alumina particles has been

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Table 1
Chemical composition of 7075 Al alloy applied in this study.

Element	Zn	Mg	Cu	Fe	Si	Cr	Mn	Al
wt%	4.9	2.5	1.1	0.1	0.1	0.2	0.2	90.4

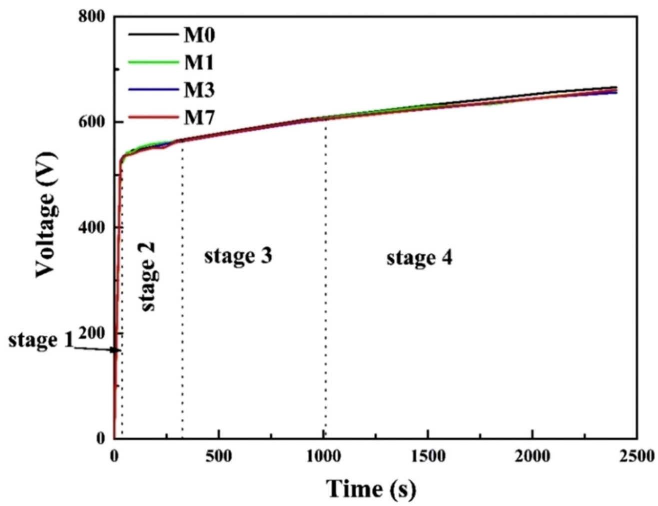

Fig. 1. Cell voltage vs. time plots for the specimens coated by PEO at the presence of different concentrations of α-Al_2O_3 particles in the electrolyte bath.

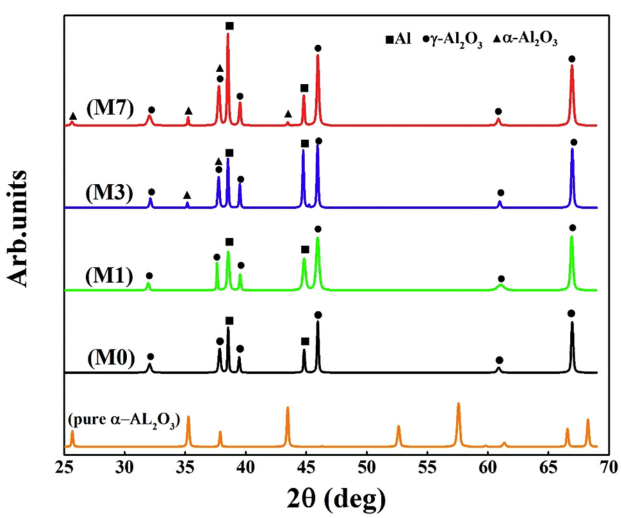

Fig. 2. GAXRD patterns of the pure α-Al_2O_3 particles and PEO coatings grown in baths containing 0, 1, 3 and 7 g·l^{-1} α-Al_2O_3 particles.

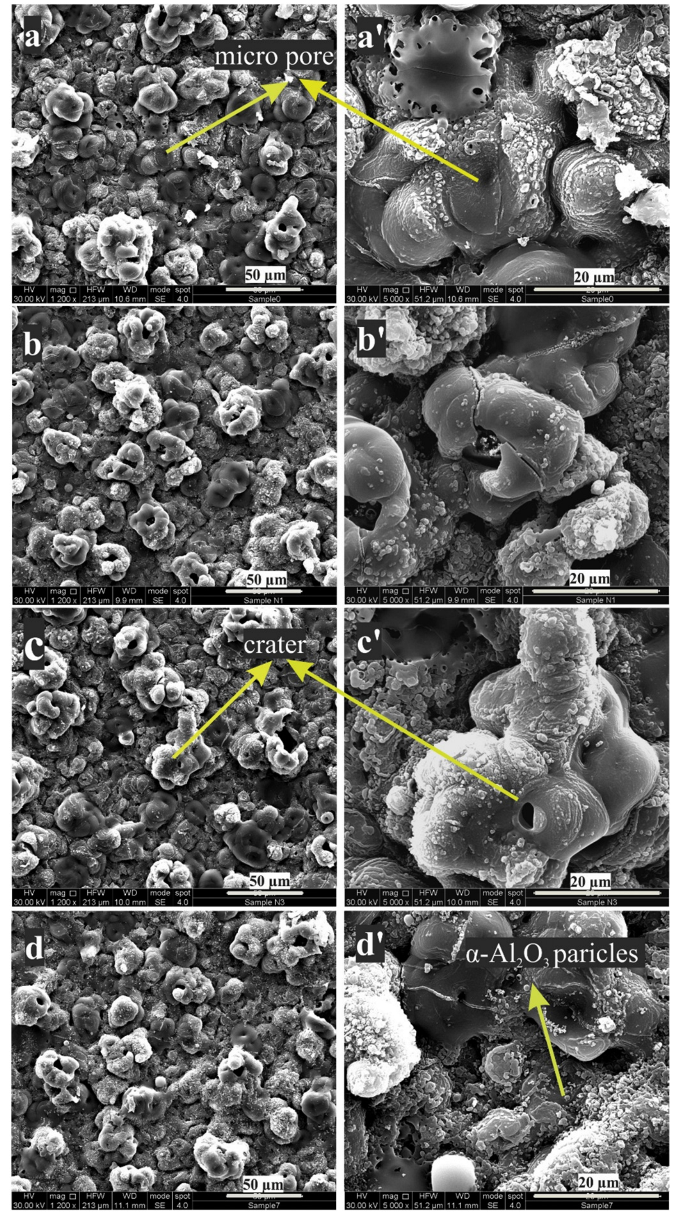

Fig. 3. Surface morphology of the PEO coated samples: a) M0, b) M1, c) M3 and d) M7.

Table 2
Measured roughness and thickness of the coatings.

Samples code	Roughness (μm)		Thickness (μm)
	Ra	Rz	
M0	5.0 ± 0.2	30.3 ± 2.9	21.3 ± 3.0
M1	4.9 ± 0.3	29.8 ± 2.1	20.5 ± 4.6
M3	5.1 ± 0.6	32.6 ± 4.7	20.9 ± 3.9
M7	5.4 ± 0.3	31.6 ± 2.3	21.3 ± 2.3

studied. Matykina et al. [13] proved that the zirconia nanoparticles can be embedded inside the coating during the PEO process which fills the porosities. A beneficial effect of titania nanoparticles incorporation on the PEO coatings grown on Al alloys is reported in ref. [6]. PEO coatings containing α-Al_2O_3 particles were produced under DC current mode on 6061 aluminum alloys in a silicate-base bath [22]. The morphology of particles-containing coatings became more compact and smooth. The electrochemical tests in highly aggressive chloride-containing environment showed that the reactive incorporation of alumina particles in the PEO coatings improved the coating corrosion resistance. However, the investigated coatings were rough and porous due to the employed DC regime. According to Arrabal et al. [21], the inert incorporation of alumina can be achieved using α-Al_2O_3 for the PEO layers with ~90 μm thickness produced under pulsed regime on Al alloy. The particles were visible at surface of the coatings. It was found that the resulted coatings showed higher wear resistance than the hard chromium-based coatings. Moreover, the results showed that increasing the particles concentration in PEO bath improves the wear behavior of the coatings [21]. However, the effect of α-Al_2O_3 particles incorporation on the corrosion resistance of such coatings was not studied.

In this work, we want to study the effect of α-Al_2O_3 particles incorporated in the coatings grown on 7075 Al alloy by the PEO process in a silicate-containing solution. The PEO process was performed using